FEED FOR CHICKENS

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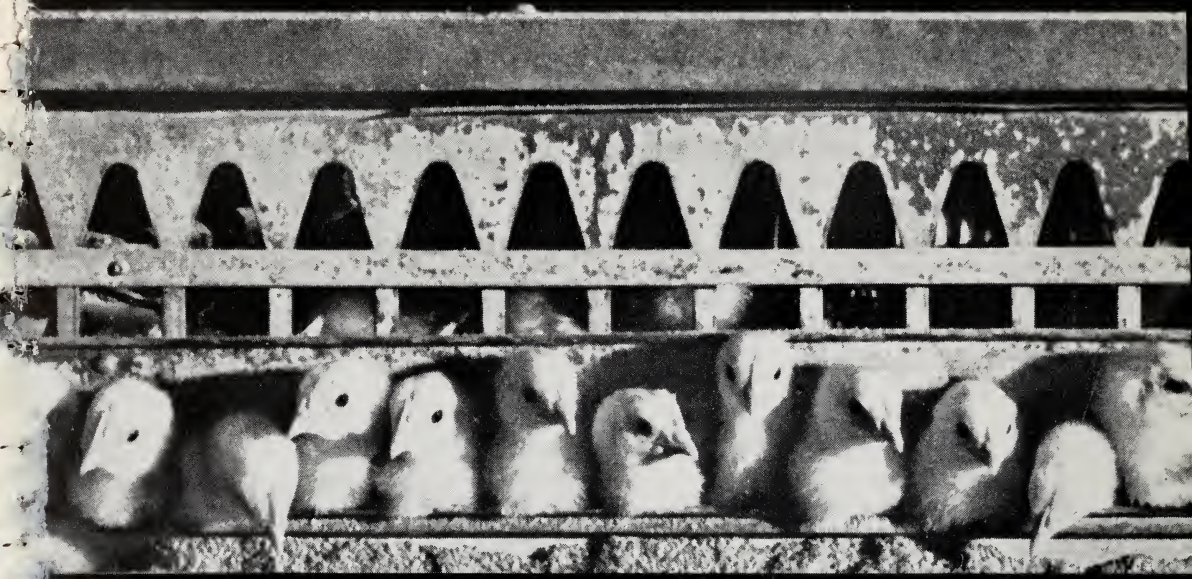

California Agricultural Extension Service
The College of Agriculture
University of California, Berkeley

CIRCULAR 159

DECEMBER 1949

What Is the Best and Most Practical Way to Provide a Balanced Diet for Chickens?

This is the big question for the poultryman who wants to maintain

- High livability
- Rapid, efficient growth of meat birds
- Efficient egg production
- Good hatchability

WITH

- Low operating costs

This Circular gives you the answer. It is a guide to chicken nutrition. The poultryman who reads it *carefully* will be prepared to get the best results in buying or mixing his own feeds—to provide a diet that meets all essential nutrient requirements for his birds.

Feed for Chickens gives you latest facts about—

1. *The Nutrients*—functions, deficiency symptoms, recommended allowances

- Energy sources
- Proteins
- Vitamins
- Minerals
- Water

2. *Feedstuffs as Sources of Nutrients*

- Cereals and other energy sources
- Protein concentrates
- Mineral sources
- Vitamin sources
- Green feeds
- Harmful components

3. *Basic Feed Formulas for Efficient Production*

- Chick-starting mashes
- Broiler-fryer mashes
- Laying mashes
- Breeding mashes
- All-purpose mashes

This circular supersedes Extension Circular 108.

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FEED FOR CHICKENS

FEED COSTS amount to more than half the total costs of poultry production. This fact obliges the poultryman to give careful consideration to the problems of poultry feeding. High livability, rapid and efficient growth of meat birds, efficient production of eggs, and good hatchability can be obtained only when feeds of high quality are used. At the same time it should be kept in mind that good management and breeding practices are just as important as good nutrition. A good feed cannot alone produce good results.

The problem is to provide a feed that is adequate nutritionally, yet is cheap enough to allow a satisfactory profit. An adequate feed contains all necessary nutrients, properly balanced and in readily available form, and a minimum of harmful substances. The nutrients which must be present in the diet are classified as **energy sources, proteins, minerals,** and **vitamins.** These are found in plants and animals, which provide the feeds and foods for domestic animals and man. Some nutrients are produced by microörganisms in the digestive tract. In ruminants, particularly, important nutrients such as amino acids and vitamins are manufactured by bacteria, yeasts, and protozoa from simple sources of nitrogen and energy.

In swine and poultry, microörganisms apparently play a comparatively small part in meeting the needs for these nutrients. **The feed must contain most of the nutrients required by these animals.**

THE NUTRIENTS

ENERGY SOURCES

The energy the chicken needs to move—to eat, digest, and utilize feed—to maintain a normal body temperature—is derived from energy sources in the diet: carbohydrates, fats, and proteins.

The chicken, like other animals, needs energy as well as other nutrients to carry on its life processes. Carbohydrates and fats are useful to the animal primarily as energy sources; proteins also furnish energy, but they are most important as structural components of the animal body.

Carbohydrates

Carbohydrates, the most important energy sources for chickens, are complex organic compounds of carbon, hydrogen, and oxygen that are manufactured by plants from water and carbon dioxide in the presence of sunlight. The various sugars, such as glucose (dextrose) and sucrose (cane or beet sugar), are well known examples of carbohydrates. Green plants combine thousands of the glucose molecules to form the large starch molecules, which are then stored in plant cells. When the animal eats starch, the large, insoluble molecules must be broken down into glucose. This process, **digestion,** is brought about by the action of digestive enzymes, which are proteins, and which are secreted into the intestinal tract of the animal.

The action of these enzymes is to split starch into glucose, which can then be absorbed into the blood stream through the intestinal wall and distributed to all parts of the body.

Some carbohydrates (like cellulose) are almost indigestible. If the diet contains very large amounts of these materials, the chicken is unable to eat enough feed to provide its needed energy.

Fats

Fats have more than twice the energy value of carbohydrates, but primarily because they are important in man's diet, they are too expensive to be used as energy sources for chickens. The animal can readily manufacture fat from carbohydrates and proteins. The energy stored in body tissues is mostly in the form of fat. Fats are composed of fatty acids, such as stearic or oleic acids, attached chemically to glycerol (glycerin).

Fats cannot be used satisfactorily in large amounts in feeds because they may become rancid, and rancid fats destroy certain vitamins needed by the animal, and may also produce a disagreeable flavor in both eggs and meat.

PROTEINS

To manufacture and maintain the tissues of the body, the chicken needs certain kinds and amounts of amino acids. These are obtained from proteins in the diet.

The active tissues of living organisms are largely proteins. Animal and plant cells manufacture these complex substances by combining the comparatively simple **amino acids** in various ways. Examples of animal materials containing large amounts of protein are muscle, blood, and feathers.

Feed proteins are first broken down into their amino acids in the chicken's digestive tract. These are then absorbed into the blood stream and carried to various parts of the body, where they are used to build new tissues, to repair old or damaged tissues, and to make enzymes and special materials such as eggs. An important problem is to supply the amino acids in the most economical way.

Nineteen amino acids are commonly present in plant and animal proteins, but the amounts of each vary a great deal in different feedstuff proteins. The tissue proteins which the animal manufactures, however, have an essentially uniform amino acid composition; so that if the animal's diet lacks a particular amino acid, the animal must manufacture it from other constituents in the diet if it is to form tissue. The chick has the ability to manufacture nine of the 19 amino acids. The remaining ten must be provided in the feed if weight loss is to be prevented. The feed must also provide some of the nine amino acids, especially glycine, which the chick cannot manufacture fast enough for efficient growth, and cystine and tyrosine, which are made from methionine and phenylalanine (see footnote, Table 1). The amounts of amino acids required in the chick's diet are given in Table 1. Because the proteins of feedstuffs provide adequate amounts of most of the amino acids, only the five listed at the top of the table need be considered.

Analyzing Feeds for Protein

Proteins and their amino acids contain nitrogen in their molecules. This provides a basis for estimating the amount of protein in feeds. The average nitrogen content of pure proteins is about 16 per cent; hence if a feed contains 8 per cent nitrogen by analysis, it is said to contain 50 per cent "crude protein." The usual method of analyzing feedstuffs for protein is to determine their content of nitrogen, express it in per cent, and multiply this percentage by $\frac{100}{16}$, or 6.25 (see Table 4, page 17).

Growth

The bird needs not only the minimum amounts of the amino acids listed in Table 1, but also additional amounts of these or other amino acids to serve as raw materials for tissue formation. It has been

found that for satisfactory growth the young chick needs about 20 per cent protein in its diet. This is the total requirement, including the essential amino acids. As the bird grows, its protein requirement gradually declines, reaching a level of about 15 per cent at maturity.

Digestibility

Some proteins (such as hair and feathers) are not digested (broken down) by the enzymes of the alimentary canal, and the animal cannot make use of amino acids from these sources. In general, ingredients of poultry feeds are highly digestible; but digestibility is not always a guarantee of nutritional value. Recent investigations have shown that some feeds formerly thought to be poorly digested because they did not promote rapid growth are actually highly digestible, but deficient in one or more essential amino acids.

Egg Production

The amounts of amino acids which the hen requires to maintain a high level of egg production have not yet been determined. But it is known that marked deficiencies of lysine, tryptophane, methionine, or isoleucine stop egg production and cause loss of body weight. Partial amino acid deficiencies result in decreased egg weight.

Deficiency Symptoms

Unfortunately there are no symptoms exclusive to amino acid deficiencies. The usual deficiency symptoms are similar to the symptoms of starvation: weakness, lack of appetite, poor growth and poor feathering. Poor appetite is the outstanding symptom of amino acid deficiencies, but it should be remembered that appetite is adversely affected by a deficiency of almost any essential nutrient.

TABLE 1—The amino acid requirements for chick growth, expressed as percentages of the diet.

Amino acid	Per cent of diet	
Arginine	1.0	May be deficient in mixtures of natural feedstuffs.
Lysine	0.9	
Methionine	0.5	
*Cystine	0.3	
Tryptophane	0.2	
Glycine	1.0	
Histidine	0.2	
Isoleucine	0.5	
Leucine	1.4	Not likely to be deficient in practical rations.
Phenylalanine	0.7	
*Tyrosine	0.7	
Threonine	0.45	
Valine	0.7	
Total	8.55	

*Cystine and tyrosine—both constituents of tissue proteins—are also included above, although they are not strictly dietary essentials. The chick's body can convert methionine to cystine and phenylalanine to tyrosine, so that cystine and tyrosine need not be in the feed if enough methionine and phenylalanine are present. In practical rations, though, we are concerned with cystine levels because virtually no feeds contain enough methionine to supply both methionine and cystine.

VITAMINS

are present in small amounts in plant and animal materials. All animals need vitamins—for normal growth, maintenance, and reproduction. Chickens need most of the vitamins required by other species, and are very exacting in their vitamin needs.

Vitamins and vital processes: The functions of the vitamins in the body are gradually being learned. Some of the vitamins are known to be necessary for the release and use of energy from carbohydrates, and one (vitamin D) is concerned primarily with the utilization of calcium and phosphorus. A deficiency of a vitamin may interfere with a vital process, so that the animal may die. Some vitamin deficiencies produce specific effects, such as paralysis or dermatitis; but the most general result of vitamin deficiencies is

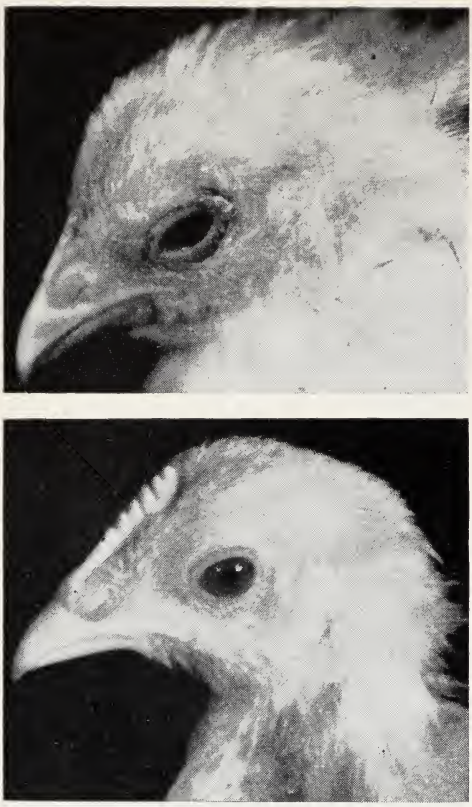


Figure 1—Above: Inflammation of the eye resulting from an acute deficiency of vitamin A. Compare with normal bird below.

poor growth. An exception is vitamin K deficiency, which causes hemorrhages but does not affect growth.

The vitamins are conveniently divided into two groups: (1) fat-soluble vitamins, and (2) water-soluble vitamins.

Fat-Soluble Vitamins

Vitamin A: Vitamin A occurs only in animal tissues, but plants contain the closely related compound **carotene,** which the animal can convert into vitamin A. Beach and Stewart, in their *Diseases of Chickens* (1942), remark that a severe deficiency of vitamin A or carotene in the ration results in "decrease in appetite; weakness and emaciation; droopiness; reddened and watery eyes (Figure 1), which may be followed by the formation of an adherent white film over the third eyelid and a mass of white cheesy material within the eyelids; the formation of yellowish-white, round, cheesy, pustule-like patches about the size of a pinhead in the mouth and throat; and occasionally the formation of masses of white, cheesy material in the cleft or elsewhere in the mouth.

"Post mortem examination of birds usually shows the kidneys to be very pale and marked with a network of very fine white lines. Occasionally a deposit of a white material is also found on the surface of the liver, on the membrane around the heart, or elsewhere on the surface of the organs." A mild deficiency results in poor growth, low egg production and reduced hatchability. In chronic cases of vitamin A deficiency, birds show generally incoordinated movements and a jerky, staggering gait.

Requirements: The vitamin A requirement of mature birds is considerably higher than that of young chicks. The minimum requirement for chicks is about 1200 International Units (I.U.)* per pound of feed, while laying hens need at least 2000 I.U. per pound. Since the amount required for good egg production is also adequate for good hatchability and chick livability, it is unnecessary to include more vitamin A in a breeding ration than in a laying ration.

Sources: The usual sources of vitamin A activity in poultry rations are alfalfa meal, yellow corn, feeding oils, or dry vitamin A concentrates. Fresh greens when available are valuable as a source of carotene (and of other nutrients too).

Vitamin A and carotene are easily destroyed by heat, by exposure to sunlight, and by contact with air, minerals, or rancid oils. Therefore feeding oils should always be stored in closed containers, in a cool dark place, and alfalfa meal should be kept out of sunlight, in a cool place. Because the conditions of alfalfa meal

* The International Unit is identical to the unit of the United States Pharmacopoeia (U.S.P. unit).

production and storage vary widely, different samples differ markedly in carotene content. Generally, the content is lowest in the early spring. The carotene content of alfalfa meal cannot be estimated accurately from the color of the meal. It is advisable to buy and use alfalfa meal on the basis of the carotene analysis of each sample.

The carotene content of alfalfa meal is often expressed in milligrams per 100 grams of meal; a meal containing 10 milligrams carotene per 100 grams has a vitamin A activity of 75,700 I.U. per pound.

Vitamin D: Animals need vitamin D for the proper utilization of calcium and phosphorus. A deficiency of vitamin D in chick rations results in rickets, which is characterized by poor growth, lameness, swelling of the hock and rib joints, and crooked breastbones (Figure 2). The bones are poorly calcified and easily bent. In adult birds, the leg bones become brittle. Egg production is low; many of the eggs are thin-shelled; and hatchability is poor.

Of the several forms of vitamin D that have been identified, some are active for the rat and other mammals, but have a very low activity for poultry. For this reason it is important that vitamin D sources for poultry be of guaranteed potency in Association of Official Agricultural Chemists (A.O.A.C.) chick units, which are measures of the form called vitamin D_3.

Sources: Ultraviolet light, a sunlight component, changes some of the sterols present in the body into vitamin D_3 and can completely fill the bird's requirement for vitamin D. However, not all birds are exposed to direct sunlight, and atmospheric conditions such as clouds, fog, and

Figure 2—The bird on the right received a diet deficient in vitamin D and was not allowed access to sunlight. Note the poor growth and crooked keel. Other causes of crooked keel are roosting on narrow roosts and mineral deficiency or imbalance.

smoke reduce the amount of ultraviolet light. Very little ultraviolet light passes through ordinary window glass. It is therefore a good practice to supply in the ration all the needed vitamin D.

Feeding oils or dry products containing synthetic vitamin D are supplements commonly used in poultry rations. Vitamin D is usually more stable than vitamin A, but its stability is affected by many of the conditions affecting vitamin A. Concentrates of vitamin D should not be premixed with mineral or granular materials such as dried milk products, because such premixing may, for some unknown reason, destroy the vitamin.

Requirements: In the absence of sunlight, growing chicks need at least 90 A.O.A.C. units of vitamin D_3 per pound of feed, while laying hens require 180 units per pound.

Vitamin E (known also as alpha tocopherol) : The most common symptoms of a deficiency of vitamin E are incoördinated movements of the legs, wings, and neck, sometimes followed by convulsions. A similar condition which was observed in the field and had been referred to as "crazy-chick disease" is now regarded as a result of vitamin E deficiency. There is also an abnormal movement of fluid into the brain and other tissues, and the skin may have a reddish appearance. The symptoms of vitamin E deficiency must not be confused with the paralysis symptoms of "fowl paralysis" (neurolymphomatosis), which is not related to vitamin E deficiency.

Requirements and sources: Chicks require approximately 1.35 milligrams of alpha tocopherol (vitamin E) per pound of feed. The requirement for adult birds has not been determined. The vitamin is present in the cereal components of poultry rations, and in dehydrated alfalfa meal, liver meal, and fresh greens, so that our usual poultry rations are not likely to be lacking in this factor. Vitamin E like vitamin A is rapidly destroyed by rancid fats; it is essential that no ingredients containing rancid fats be included in the poultry ration.

Vitamin K: This vitamin was discovered when it was observed that birds maintained on a special ration bled severely after being wing-banded. The inability of the blood to clot was found to be a result of a dietary deficiency of an essential substance, which was later identified as vitamin K. Growing chicks require about 0.18 milligram of vitamin K per pound of feed, and mature birds need at least 1.0 milligram per pound. Since alfalfa is a rich source of vitamin K, practical rations which contain as little as one per cent of alfalfa meal contain adequate amounts of this vitamin.

Water-Soluble Vitamins

Riboflavin: Riboflavin (formerly called vitamin G, or vitamin B_2) is required by chicks for normal growth and for the prevention of a condition known as curled-toe paralysis, which develops when chicks are fed a ration slightly deficient in riboflavin. The birds walk on their hocks, with their legs extended stiffly in front of them and the toes curled inward (Figure 3). The sciatic nerves show a typical enlargement.

In mature birds, lack of riboflavin means lowered egg production and a serious reduction in hatchability. Developing embryos, in eggs from hens fed riboflavin-deficient diets, show "clubbed down," edema (abnormal amount of fluid in tissues), and other abnormalities. Among such embryos there is a high death rate during the middle part of the incubation period. Further, the chicks which do hatch are less likely to survive than chicks hatched from eggs containing adequate amounts of riboflavin.

Sources and Requirements: The cereals are generally poor sources of riboflavin: other sources of the vitamin must be added to the ration to insure an adequate supply. Milk products, liver meal, alfalfa

Figure 3—A dietary deficiency of riboflavin causes curled-toe paralysis. The chick rests on its hocks, with its toes curled inward.

meal, and various fermentation products are among the rich natural sources. Synthetic riboflavin is also widely used. The requirement for chicks is about 1.35 milligrams per pound of feed; for laying hens, 0.7 milligram; and for breeding hens, 1.1 milligrams.

Although riboflavin is destroyed by direct sunlight, it is relatively stable in mixed feeds. Exposure of feed to direct sunlight for several days results in only slight losses of riboflavin.

Pantothenic Acid: Chicks fed rations deficient in pantothenic acid grow slowly and develop dermatitis. The dermatitis starts with the appearance of incrustations at the corners of the beak and on the eyelids. As the condition becomes more severe the eyes become stuck shut (Figure 4), and the body and feet may bear scabby lesions. The feathers become very brittle. Hens need pantothenic acid for egg production and good hatchability. However, the embryos of eggs from hens fed diets deficient in pantothenic acid (unlike those from hens given riboflavin-deficient diets) show no characteristic deformities.

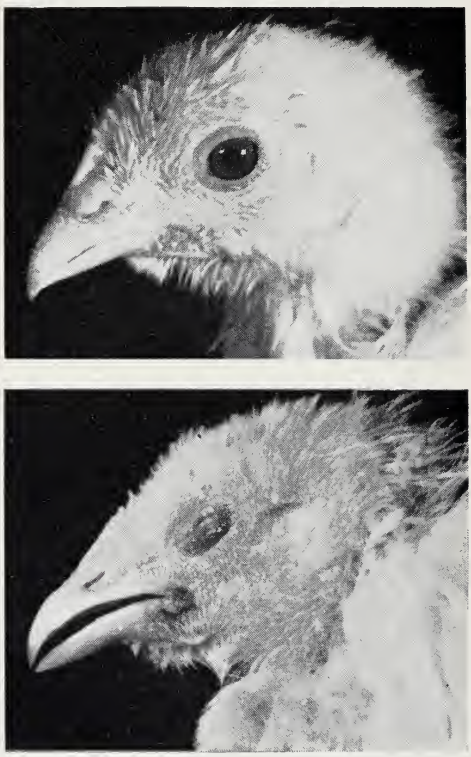
Requirements: The chick requirement for pantothenic acid is about 4 milligrams per pound of feed, while laying hens need 0.7 milligram and breeding hens 3.6 milligrams.

Sources: Among the good natural sources of pantothenic acid are liver meal, condensed fish solubles, molasses, milk products, alfalfa meal, and peanut meal.

If riboflavin is supplied by natural feedstuffs, the ration is not likely to be deficient in pantothenic acid, since feeds rich in riboflavin are usually rich in pantothenic acid.

A form of dermatitis which is sometimes observed under field conditions resembles the dermatitis of pantothenic acid deficiency, but has not been shown to be the result of a specific nutritional defi-

Figure 4—Early and late stages of dermatitis caused by pantothenic acid deficiency. Note the incrustations at the corners of the mouth, the first symptom.



ciency. No cause for this field condition is yet known.

Animal protein factor (probably the same as the cow manure factor and vitamin B_{12}): It has long been known that rations containing some animal protein concentrates promote better growth of chicks and better hatchability than straight vegetable rations. It is now apparent that the special benefit of animal products is due largely to the activity of this factor, which appears to be a vitamin. A deficiency of the factor reduces growth and hatchability.

Sources and Requirements. Rich sources of the vitamin are fish meal, fish solubles, liver meal, skim milk, and buttermilk. Some samples of meat scraps and certain fermentation products have also been found to contain the vitamin. Starting rations and breeding rations should contain 3 per cent to 5 per cent animal protein concentrates, or fermentation products which furnish equivalent amounts of the vitamin.

Choline: Chicks require choline for normal growth and for the prevention of perosis (slipped tendon). Perosis is characterized by the swelling of the hock joint, rotation of the shank outward, and in severe cases by the slipping of the tendon from the bones at the hock joint (Figure 5). Either or both legs may be affected. Birds suffering from this condition may have difficulty in obtaining enough feed and water, and may be trampled by their penmates. Perosis may also be caused by a deficiency of manganese, biotin, nicotinic acid, or folic acid. Where wire floors are used, perosis may be more frequent than where litter is used. Birds of the heavy breeds, moreover, seem to be more susceptible to perosis than birds of the light breeds.

Requirements: Adult birds have the ability to form choline in their bodies, so the choline content of their rations need not be considered. Chicks require a minimum of 0.1 per cent choline in the ration. Liver meal, fish meal, and some oil meals are good sources of choline (see Table 6).

The chick not only needs choline for the prevention of perosis, it also requires choline, or methionine or betaine for the manufacture of important tissue constituents. Rations which depend upon soybean meal as the protein concentrate are more likely to need supplements of choline (or methionine or betaine) than rations containing fish and meat products or sesame seed and sunflower seed oil meals. We cannot yet state exactly what amounts of choline, methionine, or betaine should be added to a particular ration in order to produce the best growth.

Recent studies indicate that an interrelationship exists between choline and the animal protein factor. A diet well supplied with animal protein factor requires less choline than one poorly supplied.

The Following Water-Soluble Vitamins Are Not Likely to Be Deficient in Practical Rations:

Thiamin: Thiamin, or vitamin B_1, is required by chicks for normal growth and for the prevention of nervous disorders. Chicks need approximately 0.9 milligram per pound of feed. The amount needed by adult birds is unknown, but probably does not exceed chick requirements. Since the cereals and their by-products contain large amounts of thiamin, practical poultry rations provide ample amounts of this vitamin.

Pyridoxine (Vitamin B_6): The lack of pyridoxine in chick rations retards growth and gives rise to convulsions and other nervous symptoms. Breeding hens require pyridoxine for good hatchability. The vitamin is relatively stable in feedstuffs, and there is no indication that practical rations are deficient in it.

Nicotinic Acid (Niacin): Nicotinic acid, one of the B-complex vitamins, is required in relatively large amounts for normal chick growth. Practical poultry

Figure 5—Stages in the onset of perosis, or slipped tendon. Bird above is normal. Bird at upper right is in the initial stage. Center and lower, advanced perosis.

rations are not likely to be deficient, since barley, wheat and wheat by-products, alfalfa meal, liver meal, fish meal and meat scraps are good sources of nicotinic acid.

The principal danger of a nicotinic acid deficiency occurs when corn is fed in large amounts; corn is particularly low in nicotinic acid. Corn is also low in tryptophane, which the chick can use for the manufacture of nicotinic acid. Nicotinic acid deficiency is one of the many causes of perosis (see **choline** above). The chick requirement for growth is approximately 7 milligrams per pound.

Biotin: Biotin is needed by the chick for normal growth and the prevention of perosis and dermatitis. The dermatitis caused by a biotin deficiency is different from the dermatitis of pantothenic acid deficiency. Its first symptom is a thickening of the skin on the bottoms of the feet, followed by a cracking of the skin. Later, as the condition becomes more severe, the corners of the mouth, the eyes, and the body skin may be involved.

Breeding hens need biotin for good hatchability; low hatchability and malformed embryos result when the ration contains inadequate amounts of biotin.

The chick needs about 0.04 milligram of biotin per pound of feed. Since corn, barley, soybean oil meal, and alfalfa meal all contain more than this amount per pound, a deficiency of biotin in poultry feeds is very unlikely. However, feeding raw egg white causes the biotin in the ration to become unavailable to the bird. Egg white should always be cooked to make biotin available, and also to prevent the spread of pullorum disease.

Folic Acid (Pteroylglutamic Acid): This vitamin is required by chicks for normal growth and for the prevention of anemia. Folic acid deficiency also causes poor feathering and poor hatchability. Approximately 0.2 milligram of folic acid per pound of feed is required by chicks; however, the requirement has been found to differ among different strains. Alfalfa meal, soybean oil meal, and liver meal are good folic acid sources. Because practical rations generally cover folic acid requirements, no special consideration need be given to this vitamin.

Ascorbic Acid (Vitamin C): Ascorbic acid is needed by the tissues, but birds have the ability to make sufficient amounts of it. It is therefore unnecessary to supply additional ascorbic acid to the ration.

MINERALS

All birds need a continuous supply of minerals—to form new bone and soft tissue in the growing bird—to replace minerals lost by excretion—to form eggs, and for other vital functions. Common poultry feedstuffs may not supply all mineral requirements.

The minerals known to be required by chickens are calcium, phosphorus, sodium and chlorine (combined as sodium chloride, common salt), magnesium, manganese, potassium, iron, copper, and iodine. Sulfur must be provided by the amino acids methionine and cystine. Cobalt and zinc, though needed by some other animals, have not yet been shown to be needed by chickens.

The requirements for minerals which common poultry feedstuffs may not adequately supply are given in Table 3.

Calcium and Phosphorus

Calcium and phosphorus, the most important constituents of bone, are required in large amounts by the growing bird. The laying hen also needs large amounts of calcium for the manufacture of egg shells. Both calcium and phosphorus are needed for the normal functioning of many tissues besides bone.

For the efficient utilization of calcium and phosphorus, the animal requires an adequate amount of vitamin D. A deficiency of vitamin D increases the calcium and phosphorus re-

quirements. Also, the **ratio** of calcium to phosphorus in the diet affects the vitamin D requirement: when the ratio of calcium to phosphorus deviates very far from two to one, more vitamin D is needed to maintain the efficient use of these minerals.

Some of the phosphorus found in plant cells is not readily available to the chicken; good diets contain some inorganic phosphorus source.

A lack of calcium, phosphorus, or vitamin D results in poor growth and poor calcification (mineralization) of the bones—the nutritional disease condition called **rickets.**

Sodium Chloride (Salt)

The requirement for salt is not more than 0.5 per cent of the diet. Very low levels may result in poor growth; very high levels may be poisonous.

Manganese

Manganese deficiency in chick rations results in perosis, a disease of the hock joint (see **choline** above), and in abnormally short and poorly mineralized bones. In laying hens, a manganese deficiency results in poor production, thin egg shells, low hatchability, and embryo deformities. An excess of calcium or phosphorus raises the manganese requirement. Many feedstuffs do not contain enough manganese to meet the bird's needs; supplements of manganese salts are therefore added to most poultry rations.

Magnesium

Magnesium deficiency results in poor growth and in convulsions (caused by a breakdown of certain brain cells). Although the chicken's magnesium requirement is high (180 milligrams per pound), practical rations always supply the needed amount. On the other hand, feeding excessive amounts of magnesium results in poor growth, poor calcification of the bones, and production of thin-shelled eggs.

Iron and Copper

Iron is required for red blood cell formation; copper aids in iron utilization. Poultry feedstuffs ordinarily contain more than enough of both minerals to satisfy the chicken's needs.

Potassium

The diet of the chick should contain about 0.3 per cent potassium to promote best growth. Since vegetable materials contain relatively large amounts of potassium, a deficiency in practical rations is unlikely.

Iodine

The animal needs iodine for the manufacture of thyroxine (the thyroid hormone). In addition, some feedstuffs, such as soybean oil meal, contain substances which cause goiter (enlargement of the thyroid gland); iodine—in the form of potassium iodide—is necessary in the diet to prevent this condition. Poultry of all ages require about 0.5 milligram of iodine per pound of feed. When marine products (for example, fish meal or shell flour) are included in the ration, supplementary iodine is not usually needed. But when high levels of soybean oil meal are fed, it is desirable to use iodized salt in the ration.

WATER

Water is not usually regarded as a nutrient, but it is essential for all poultry. Birds in fact can live longer without feed than without water. Clean water should be kept before the birds at all times.

DIAGNOSING NUTRITIONAL DEFICIENCIES

It is usually difficult to diagnose nutritional deficiencies under field conditions because **infectious** diseases so often complicate the picture. For this reason we urge the poultryman to take advantage of the free diagnostic service offered by the state and county pathological laborato-

TABLE 2—Symptoms of nutritional deficiencies in chickens.

Symptoms	Age	Diagnosis	Nutrients involved
Legs weak and hocks swollen. Beak pliable and bones easily bent. Ribs beaded.	2 to 15 weeks	Rickets	Lack of calcium, phosphorus, or vitamin D; too high levels of calcium or phosphorus.
Hocks swollen and legs bent to side. Tendon slipped from normal position.	0 to 15 weeks	Perosis	Lack of manganese most common; also lack of choline, biotin, folic acid, or nicotinic acid; or excess of calcium or phosphorus.
Chicks walk on hocks, feet extended stiffly with toes curled inward.	1 to 15 weeks	Curled-toe paralysis	Riboflavin deficiency.
Scabby lesions at corners of mouth, eyelids, bottoms of feet, vent. Feathers broken, giving ragged appearance.	2 to 15 weeks	Dermatitis	Lack of pantothenic acid or biotin. Another kind of dermatitis sometimes occurs under field conditions, but there is no evidence suggesting that a simple dietary deficiency is the cause.
Eyes watery, third eyelid opaque, cheesy material in mouth and eyes.	2 weeks and older	Vitamin A deficiency	Vitamin A deficiency.
Gizzard linings rough and sometimes eroded through to the muscular layer. Growth not affected.	Any age	Gizzard erosion	Condition may be caused by many nutritional deficiencies or by poor management practices.
Chicks pull feathers and pick each other, particularly the toes and around vent.	Any age	Cannibalism	May be started by almost any nutritional deficiency or by poor management practices. May be controlled by correcting deficiency, providing adequate floor space, or diverting birds' attention from picking by feeding greens or other special supplements. Use of medicated ointment and red lights beneficial with chicks. Removing part of upper beak or use of certain preventive or protective devices effective.

ries. Details of the services available will gladly be given by your county farm advisor.

If it is impossible to obtain laboratory diagnosis, the information summarized in Table 2 may be helpful in recognizing certain nutritional deficiencies. Some symptoms, such as curled-toe paralysis, are quite specific results of a nutritional deficiency. Others, such as dermatitis, gizzard erosion, and cannibalism, are not related exclusively to malnutrition. For this reason, laboratory verification of the suspected deficiency is most desirable.

TABLE 3—Nutrient allowances for chicken rations.[1]

	Crude protein per cent	Calcium per cent	Phosphorus per cent	Salt per cent	Manganese milligrams (mg.) per lb.	Vitamin A activity I.U./lb.	Vitamin D A.O.A.C. units per lb.	Riboflavin mg./lb.	Pantothenic acid mg./lb.	Choline mg./lb.	Animal protein factor source
Chick-starting ration 0–8 weeks	20	1.6	0.8	0.5	25	2000	180	1.6	5.0	700	+ +[3]
Chick-growing ration 8–18 weeks	16	1.6	0.8	0.5	25	2000	180	0.9	...	....	+
Hen-laying ration	15	2.0[2]	0.8	0.5	15	3300	450	0.9	2.5	....	0
Hen-laying mash (to be fed 50–50 with grain)	20	2.0[2]	1.0	1.0	25	6600	900	1.3	1.8	....	0
Hen-breeding ration	15	2.0[2]	0.8	0.5	15	3300	450	1.3	5.0	....	+
Hen-breeding mash (to be fed 50–50 with grain)	20	2.0[2]	1.0	1.0	25	6600	900	2.1	6.8	....	+ +

[1] Adapted from "Recommended Nutrient Allowances for Poultry," National Research Council (Revised Nov. 1946). These allowances differ from some of the requirement figures given in the text. Those in this table include a factor of safety considered desirable in practical diets.

[2] Additional calcium for egg-shell formation is usually supplied by shell or limestone fed free choice.

[3] Plus and zero signs are relative indications of animal protein factor requirements. As yet we have no absolute units for this factor.

RECOMMENDED NUTRIENT ALLOWANCES

In formulating rations, the poultryman should first calculate the amounts of the various nutrients which the chicken will actually derive from the feed, and then compare them with the bird's requirements. The stability of the various nutrients—under different conditions of grinding, mixing, storing, and feeding—is an important consideration. Of the various nutrients, vitamin A, carotene, and vitamin E are the least stable, while the mineral elements are the most stable. The nutrient allowances given in Table 3 take account of variations in stability of the nutrients; but if these allowances are to hold good, feedstuffs should be stored for the shortest time consistent with economy of purchase, and should if possible be kept in dark, cool, dry places. If these precautions are taken, a given feed which meets the calculated allowances should prove adequate in practical use.

Note: The allowances given in Table 3 are not all equally accurate. For example, the choline and pantothenic acid allowances for chick-starting rations may be unnecessarily high. This excess is a margin of safety. We are not yet sure of the exact content and availability of these and other vitamins in feedstuffs.

FEEDSTUFFS AS SOURCES OF NUTRIENTS

Up to this point we have considered the nutrients as well-defined groups of substances in order to explain their functions. In practical feeding, however, we are not ordinarily concerned with separate nutrients, but with mixtures of nutrients as they occur in feedstuffs. This section gives information on the nutritional value of different feedstuffs for poultry.

To insure maximum uniformity and to protect the industry, the California State Department of Agriculture, Bureau of Field Crops, has defined the various feedstuffs in terms of raw materials used, methods of processing, and chemical analysis. These definitions have been published in "Commercial Feeding Stuffs Regulations"—copies are obtainable from the Bureau of Field Crops—and are essentially the same definitions as those adopted by the Association of American Feed Control Officials. They make possible the enforcement of laws designed to protect both feed mixers and users.

The amounts of the various nutrients contained in feedstuffs are presented in Tables 4, 5, and 6.

Feedstuffs may be grouped conveniently into energy, protein, vitamin, and mineral sources, although there is some overlapping between these groups. The cereals and cereal by-products, for example, are primarily carbohydrate (energy) sources, but they furnish appreciable amounts of protein, many vitamins (especially thiamin and vitamin E), and minerals (particularly potassium, magnesium, and iron).

ENERGY SOURCES

Cereals and Cereal By-Products

Barley is the most common feed grain in California. When its price is comparatively low, it may well be fed as the principal grain. Birds raised on other grains may not consume whole barley readily, but birds trained to eat it early enough will consume it freely.

In experiments carried out at this Station over a four-year period, it has been found that chicks fed barley grow somewhat more slowly than those fed yellow corn. Birds raised on rations containing barley as the principal grain and fed these rations during the laying period, however, were found to have a lower reproductive mortality rate than those similarly fed yellow corn rations.

The feeding value of different grades of barley is roughly proportional to the weight per bushel. Generally, the heavier the barley the higher is its feeding value. Light-weight barley should not be used unless it can be bought at correspondingly lower prices than the heavier barley. Barley screenings and hulls should never be used as poultry feeds.

Corn: This valuable grain for poultry may be used when available at a fair price in comparison with other grains. Corn is especially valuable in meat-bird rations, which must promote rapid growth. Yellow corn is more desirable than white corn, because it contains a yellow pigment (cryptoxanthin) which has some vitamin A activity. Yellow corn is not a rich source of vitamin A activity, but it will contribute significant amounts to the ration when high levels are fed. Yellow corn also provides a yellow pigment (xanthophyll) for egg yolks and for the skin and shanks of birds that normally have yellow skins. Argentine flint corn has the same feeding value for poultry as domestic corn, but it contains more of the skin- and yolk-coloring pigments.

Milo: For this feedstuff see *Sorghum grains*, page 18.

TABLE 4—Average proximate composition of feedstuffs used for poultry.*

Feedstuff	Crude protein	Crude fat	Crude fiber	Ash
	per cent	per cent	per cent	per cent
Alfalfa leaf meal	20.3	3.2	17.9	10.2
Alfalfa meal	16.6	2.6	25.6	8.8
Alfalfa, fresh	4.7	0.8	8.0	2.3
Babassu oil cake meal	23.9	6.9	12.0	5.7
Barley	9.7	2.3	6.2	2.7
Beans, cull lima	22.3	1.1	4.6	6.0
Blood meal	81.6	0.9	0.6	5.1
Bone meal, raw	24.6	5.6	0.6	58.8
Bone meal, special steamed	7.5	0.7	0.6	80.5
Brewers' dried grains	26.2	6.6	14.7	4.0
Buttermilk, condensed	10.9	1.9	0.	2.2
Buttermilk, dried	32.9	5.9	0.	7.9
Coconut meal	20.5	7.8	10.4	6.8
Corn	9.9	4.2	2.1	1.5
Corn germ meal	14.3	6.0	5.1	4.2
Corn gluten feed	24.8	2.8	7.4	6.1
Corn gluten meal	45.0	2.1	4.1	2.6
Corn oil meal	23.2	5.5	10.4	2.4
Cottonseed meal (40% protein)	40.6	6.6	11.3	6.5
Distillers' grains with solubles	29.	9.	7.	4.
Fish meal	66.3	7.7	0.5	15.6
Fish solubles, condensed (50% solids)	33.5	4.	0.	8.9
Linseed oil meal	30.9	6.1	9.5	5.5
Liver meal	67.9	15.4	1.4	5.4
Meat scraps	60.1	10.0	2.2	20.9
Meat and bone scraps	50.6	9.7	1.8	29.9
Milk, dried skim	34.8	1.2	0.	7.6
Milo	9.6	3.0	2.0	1.9
Molasses, cane	3.6	0.	0.	9.8
Oats, Pacific Coast	9.8	5.4	10.5	3.6
Peanut oil meal	45.9	7.0	6.1	5.2
Potatoes, dried	10.4	0.3	2.0	4.3
Rice bran oil cake meal	16.0	8.2	9.2	13.4
Rice millrun bran	11.7	15.7	9.5	9.8
Safflower seed oil meal	17.4	2.8	40.0	2.5
Screenings oil feed	33.7	7.6	10.2	5.8
Sesame seed oil meal	41.8	9.9	6.1	12.1
Soybean oil meal	44.0	5.4	5.6	5.5
Sunflower seeds	16.1	24.7	27.9	3.1
Sunflower seed oil meal	49.2	1.6	10.4	6.9
Wheat	10.8	2.1	2.7	1.8
Wheat bran	15.6	4.0	8.5	5.4
Wheat middlings	14.8	3.5	3.0	2.4
Wheat millrun	15.6	4.1	7.7	4.7
Wheat shorts	15.8	4.5	5.8	3.8
Whey, condensed	6.3	0.	0.	4.8
Whey, dried	12.5	0.	0.	10.4
Yeast, pure dried	47.1	1.9	4.6	6.8
Yeast culture	13.7	4.5	3.8	3.6

* From data obtained by Feed Control Laboratory, Bureau of Field Crops, California Department of Agriculture.

Oats are a good poultry feed, though even heavy oats have a comparatively high fiber content because of the hulls. This grain offers no advantages over other grains such as barley, but it may be used satisfactorily when its price is consistent with its feeding value.

Rice is low in protein but high in digestible energy (see next column). The superior grades of rice are too costly for use in poultry rations, but cracked and shrunken grains can sometimes be obtained at reasonable prices.

Rice by-products: Fresh rice bran and rice polish are nutritionally valuable, palatable feedstuffs. But since their fat content is high they should not constitute more than ten per cent of the mash. Also, they become rancid soon after milling, and should not be stored very long. Properly used, rice by-products give satisfactory results in poultry rations.

Recently a defatted rice bran product—rice bran oil cake meal—has become available for poultry feeding. This product does not become rancid during storage, and feeding trials have shown it to be comparable to wheat bran or millrun in nutritional value.

Rye: Sticky droppings and poor growth result from feeding rye to young chicks, so that this grain is unsatisfactory as a feedstuff for young birds. Older birds can tolerate as much as ten per cent in the mash.

Screenings from grain-cleaning operations may usually be substituted for cereals to the extent of five per cent of the mash. They vary greatly in composition and value, and should be used cautiously.

Sorghum grains: Milo, Egyptian ("gyp") corn, kaffir, and other sorghums are important poultry feed grains in California. They are low in fiber and have high digestible-energy values. Milo may well be used in place of corn in California poultry rations when availability and comparative prices warrant. Feeding trials at this Station indicate that good quality milo has about 92 per cent of the feeding value of yellow corn in chicken rations.

Water-grass seed, available from rice-cleaning processes, can be used extensively in poultry rations when its cost is comparable to the cost of barley. Because its fat becomes rancid quickly, it should be used as soon after grinding as possible.

Wheat: This popular grain for poultry in California ranks slightly below yellow corn in feeding value, but is above barley and oats. But because it is so widely used as human food, it is often comparatively expensive for use as poultry feed.

Wheat by-products: The most important wheat by-products are wheat bran, millrun, and middlings. These popular poultry feedstuffs are lower in digestible-energy value than whole wheat, but they contain somewhat higher amounts of valuable proteins, minerals, and vitamins. These relatively cheap feedstuffs may be profitably used in many poultry rations.

Digestible-Energy Values of the Common Grains

In deciding which of the available grains to feed, the poultryman should consider their digestible-energy values for chickens. On the basis of calculations, 100 pounds of yellow corn contains total digestible nutrients (carbohydrates, proteins, fats) equivalent in energy-producing value to 75.5 pounds of starch. Wheat has a corresponding value of 72.1; milo, 69.5; barley, 66.1; oats, 63.6.

In other words, 105 pounds of wheat, 108 pounds of milo, 114 pounds of barley, and 119 pounds of oats each have a digestible-energy value equivalent to 100 pounds of corn. Expressing the comparison in percentage: wheat has 95.5 per cent the energy value of corn; milo has 92.0 per cent; barley 87.5 per cent; oats 84.3 per cent.

Note that since protein concentrates such as fish meal, oil meals, and meat

scraps are used primarily as sources of protein rather than of energy, it is not necessary to rate them according to their digestible-energy values.

Other Energy-Source Feedstuffs

Carrots: Dried carrots, either whole or roots only, have been used successfully to replace grain to up to ten per cent of the ration.

Grape pomace meal is too high in fiber to make a satisfactory feedstuff for chickens.

Legumes (cull lima beans, mung beans, field peas, cow peas, pigeon peas, etc.): Feeding trials at this and other stations have shown that these feedstuffs may be used to replace grain to up to five to ten per cent of the ration. Although these legumes contain 20 to 25 per cent protein, they are used primarily as energy sources.

Molasses: Molasses (cane or beet), an energy concentrate, can be fed in small quantities when its price warrants. It should never be fed at levels higher than 2½ per cent of the total ration, because it has a laxative effect. Molasses is rich in pantothenic acid and potassium, and helps reduce the dustiness of mashes, although it is difficult to mix into the ration. For easier mixing, dehydrated molasses may be used—four pounds are about equal to five pounds of liquid. Molasses may also be fed as molasses-bran, a mixture containing about 15 per cent molasses.

Orange meal: This has been suggested as a possible feedstuff, but tests made here have shown orange peel and pulp meal to be almost valueless for poultry.

Potatoes: Small and otherwise inferior potatoes are sometimes fed to poultry. About five pounds of potatoes are required to replace one pound of grain. They should be cooked before using.

Raisins: Among the fruit by-products tested at this station are cull raisins. They can be used to replace grain to up to ten per cent of the ration.

Safflower seeds and oil meal are sometimes available as poultry feedstuffs. They are high in fiber and are less valuable than cereal grains as energy sources, but they furnish some fair-quality protein.

Sunflower seeds are sometimes used in the scratch feed. The protein of the inner part of the seed is of excellent quality, but the high fiber content of the hull decreases the value of the seed.

Tomato pomace meal is high in fat and fiber, and although it contains some carotene is not a recommended poultry feedstuff.

Yeast culture is a feedstuff containing a small amount of live yeast dried on ground grains. With some rations, the growth rate of cockerel chicks is increased slightly when two per cent yeast culture is added to the mash. The reason for this growth effect is not yet known.

PROTEIN CONCENTRATES

The protein content of the cereals is not sufficient to satisfy the needs of the chicken. Various protein concentrates are used to supply the additional needed protein. For the chick, protein concentrates furnish about two-thirds of the total protein of the diet, while for the hen they provide less than half of the total protein.

Since protein requirements are actually the amino acid requirements considered together, it is often more convenient to speak of amino acid requirements simply in terms of protein requirements. The total protein requirement is about 20 per cent for young chicks and 15 per cent for adult birds. The protein must be present in digestible form, and it must furnish the required amounts of the various amino acids.

Animal Protein Concentrates

Animal protein concentrates are often sold on the basis of protein content, as

TABLE 5—The amino acid composition of some feedstuffs, expressed as percentage of total feedstuffs.*

Feedstuff	Protein	Arginine	Lysine	Methionine	Cystine	Tryptophane
Alfalfa meal	17	1.1	0.85	0.39	0.31	0.32
Barley	10	0.48	0.18	0.29	0.18	0.11
Corn	10	0.38	0.22	0.27	0.19	0.07
Corn gluten meal	43	1.4	0.86	1.0	0.82	0.34
Cottonseed meal	43	3.2	1.2	0.78	0.95	0.47
Fish meal	65	3.8	3.7	1.9	0.65	0.78
Fish solubles, condensed	35	1.5	1.7	0.52	0.21	0.14
Linseed oil meal	32	2.3	0.93	0.73	0.61	0.55
Meat scraps	55	3.9	2.8	0.94	0.66	0.38
Milk, dried skim	35	1.4	2.6	1.0	0.42	0.46
Milo	10	0.34	0.25	0.15	0.20	0.08
Oats	10	0.60	0.33	0.23	0.18	0.13
Peanut oil meal	44	4.4	1.3	0.57	0.70	0.40
Sesame seed oil meal	42	3.7	1.2	1.4	0.55	0.63
Soybean oil meal	44	2.8	2.7	0.79	0.66	0.53
Sunflower seed oil meal	46	3.8	2.0	1.6	0.73	0.60
Wheat	13	0.52	0.36	0.17	0.23	0.14
Wheat bran	16	0.96	0.53	0.19	0.27	0.24
Whey, dried	12	0.36	0.90	0.38	0.31	0.24
Ideal ration for chick growth	20	1.0	0.9	0.5	0.3	0.2

* Adapted from Almquist, H. J., The amino acid requirements of avian species, in Proteins and Amino Acids in Nutrition, p. 231, M. Sahyun, Ed., Reinhold (1948).

determined by analysis. Where this method is followed, a unit of protein is equal to one percentage point of crude protein (the nitrogen content multiplied by 6.25; see page 4).

Fish meals are made from whole bony fish or from fish cannery scrap, by a wet-rendering process: the raw material is cooked, and the mixture of water and oil is pressed out from the solids, which are then dried, ground, and sold as fish meal. The oil is separated from the water extract and sold as feeding oil or for manufacturing purposes, while the water-extract is often concentrated and sold as condensed fish solubles. If the fish meal is dried at a low temperature, the product will be highly digestible and have a high nutritional value.

On the Pacific Coast most fish meal is made from the sardine (pilchard), herring, tuna, or mackerel. The proteins of these products are generally of good quality: they provide all the essential amino acids in digestible form. These fish meals are usually good sources of arginine, lysine, and methionine, and can therefore be used to supplement proteins which are deficient in these amino acids.

Shark meals have generally been found inferior to other fish meals as sources of protein for poultry. They contain appreciable amounts of urea, which contains nitrogen, but actually has no protein value for chickens (see page 4). Recently, however, a new process has been developed by which a shark meal of improved quality can be produced.

Carp meal, ratfish meal, and other fish meals are of fairly good quality when properly prepared. The available tonnage is limited.

Condensed fish solubles contain proteins which are low in certain amino acids, and are therefore inferior to most fish meals as protein sources for poultry. The main reason for using fish solubles and similar products in the ration is that they contain the animal protein factor (see page 10).

Meat packing by-products are produced by both dry- and wet-rendering processes. **Meat scraps,** the dry-rendered residues from animal tissues, and **tankage,** the wet-rendered product, vary greatly in quality according to the raw materials used and the methods of manufacture. They are generally good sources of arginine and lysine, but are usually deficient in cystine and methionine. Tankage containing significant amounts of blood is also deficient in isoleucine.

Blood meal protein is a good source of arginine and lysine, but is deficient in methionine as well as isoleucine. It is a good supplement for corn gluten meal protein, which is a good source of isoleucine but is deficient in lysine and arginine.

Liver meal and **liver and glandular meal** are fairly good sources of most amino acids, but like other meat packing by-products are often deficient in methionine and cystine. The chief use of these meals is to supply vitamins; other meat by-products are more important as amino acid sources.

Milk products that are fed to poultry are usually dried or condensed by-products obtained in the manufacture of butter and cheese for human use. Fresh skim milk and buttermilk, however, are also satisfactory feedstuffs, if they are cheap enough. They should not be fed in metal containers. The cost per pound of dry matter, or the cost per pound of protein, are the factors which should determine whether a fresh, condensed, or dried product is to be used.

Some milk products—such as dried whey—are low in protein, but are valuable in the ration because they contain significant amounts of riboflavin and other water-soluble vitamins.

Vegetable Protein Concentrates

Soybean oil meal, our most important vegetable protein concentrate, is a good source of all the amino acids except methionine (in which it is slightly deficient). The quality of soybean oil meal depends largely on proper heat treatment of the meal during or after removal of the oil from the beans. As a result of such treatment, the methionine of the soybean protein is made available to the chicken. If the meal is overheated, a portion of both the methionine and lysine becomes unavailable; feeding such overheated meal to chicks also tends to cause "pasting up," a condition characterized by sticky droppings which adhere to the down feathers around the vent. Properly heat-treated soybean oil meal is an excellent source of lysine, and is well used to supplement the cereal grains, sesame seed oil meal, and other vegetable protein concentrates, which are low in lysine.

When soybean oil meal is used to replace fish and meat products in the ration, care must be taken to provide riboflavin, the animal protein factor, and minerals, particularly calcium and phosphorus.

Raw soybeans should not be fed to chickens, mainly because the methionine they contain is largely unavailable.

Sesame seed oil meal, like soybean oil meal, is produced by removing the oil from the seeds. But unlike soybean oil meal, sesame seed oil meal does not require heating to allow utilization of all its amino acids. Sesame seed protein contains a large amount of methionine but only a small amount of lysine. It is best used together with some product which is a good source of lysine but is deficient in methionine. A mixture of two parts soybean oil meal to one part sesame seed oil meal is an excellent source of amino acids

for the growing chick. The mixture, however, does not cover the lysine deficiencies of the cereal grain proteins which are also present in the diet.

Sunflower seed oil meal, the most complete vegetable protein concentrate known, provides adequate amounts of all the amino acids. However, it does not contain the excess of lysine required to cover the deficiency of the cereal grains. An excellent source of methionine, it is best used as a supplement to soybean oil meal.

Corn gluten meal, a by-product of the manufacture of cornstarch, is not a very good protein source for poultry because it is low in arginine, lysine, and tryptophane. For best results it should be used with such a product as tankage or blood meal.

Peanut oil meal is a poor source of methionine and lysine and is therefore one of the poorer sources of protein for poultry, unless properly supplemented.

Cottonseed meal, which is deficient in lysine and methionine, can be used in mashes for growing birds but should not be fed to laying hens because it causes mottled or olive-colored yolks in fresh eggs and "pink whites" in storage eggs.

Linseed oil meal contains an unidentified substance which retards the growth of chicks. The addition of the vitamin pyridoxine to the ration will counteract the action of this substance, as will soaking the linseed oil meal in water for 12 hours. Properly processed linseed oil meal has been found to be a good source of all the required amino acids except lysine.

MINERAL SOURCES

The minerals requiring the greatest attention in poultry rations are calcium, phosphorus, manganese, sodium chloride (common salt), and iodine. Certain animal products (for example, meat and bone scraps, fish meal) contain fairly large amounts of these minerals, but most vegetable feedstuffs are poor sources. Minerals, like other feedstuffs, should be purchased on the basis of price and quality. It is unnecessary to buy expensive mineral mixtures for poultry.

Calcium and Phosphorus

A calcium supplement is usually added to mashes as calcium carbonate, in the form of ground limestone, calcite, or oyster or clam shell. The cheapest-per-pound source of calcium should be used. Laying hens need fairly large amounts of calcium for egg-shell formation, and therefore hoppers containing crushed limestone or shell should be available to the hens at all times. Dolomitic limestone should not be used because it has a high magnesium content. It is important to note that none of these calcium sources is a substitute for the hard, insoluble grit which poultry receiving whole grains require.

Bone meals are used primarily as phosphorus supplements, but they also contain large amounts of calcium. Special steamed bone meal is the form most commonly available.

Defluorinated rock phosphate (rock phosphate from which most of the fluorine has been removed) is a suitable calcium and phosphorus supplement for poultry. By definition it contains no more than one part of fluorine to 40 parts of phosphorus. The total poultry ration should contain no more than 0.035 per cent fluorine. If it is necessary to use raw rock phosphate only small amounts should be used.

Dicalcium phosphate may also be used as a source of calcium and phosphorus in poultry rations. It is prepared by dissolving bone meal or phosphate and precipitating the dicalcium phosphate in pure form.

Phosphatic clay (soft phosphate with colloidal clay) contains approximately 18 per cent calcium, 8.5 per cent phosphorus, and 1.2 per cent fluorine. Like other phosphate products, it should

TABLE 6—The mineral and vitamin contents of common feedstuffs.

Feedstuff	Calcium per cent	Phosphorus per cent	Manganese mg./lb.	Riboflavin mg./lb.	Pantothenic Acid mg./lb.	Choline mg./lb.	Vitamin A activity I.U./lb.
Alfalfa leaf meal, sun-cured	1.90	0.22	14.	6.5	13.	400	83,000[1]
Alfalfa meal, dehydrated	1.43	0.21	12.	6.5	17.	400	67,000[1]
Alfalfa meal, sun-cured	1.43	0.21	12.	6.5	12.	400	33,000[1]
Barley	0.05	0.38	6.	0.5	3.2	530	0
Bone meal, special steamed	29.	14.	6.	0.	0.	0	0
Buttermilk, dried	1.4	0.8	0.2	14.	20.	500	0
Clay, phosphatic	18.	8.	....[2]	0.	0.	0	0
Corn, yellow	0.01	0.28	2.	0.6	3.2	200	3100
Corn gluten meal	0.10	0.65	2.	0.9	6.3	135	10,000
Cottonseed meal	0.24	1.11	8.	4.	6.4	1200	0
Distillers' solubles, dried	0.3	1.2	32.	6.	12.	2500	1000
Fish meal	5.5	3.2	18.	3.	2.4	1500	0
Fish solubles, condensed (50% solids)	0.08	0.85	....	6.	18.	1000	0
Limestone	38.	0.	91.	0.	0.	0	0
Linseed oil meal	0.33	0.86	18.	1.5	3.2	800	0
Liver and glandular meal	0.7	0.8	2.	15.	47.	4700	0
Meat scraps	8.7	4.3	8.	3.	3.5	1300	0
Meat and bone scraps	10.9	5.2	4.5	2.	2.	1300	0
Milk, dried skim	1.3	1.0	0.5	7.	15.	500	0
Milo	0.01	0.34	7.	0.7	4.	....	0
Molasses, cane	0.6	0.1	....	0.3	22.	300	0
Oats	0.1	0.3	15.	0.5	4.5	430	0
Peanut oil meal	0.18	0.57	....	1.5	24.	780	0
Sesame seed oil meal	2.0	1.6	....	2.3	2.7	....	0
Shell, clam or oyster	39.	0.	145. (clam) 55. (oyster)	0.	0.	0	0
Soybean oil meal	0.28	0.66	14.	1.5	6.3	1300	0
Sunflower seed oil meal	....	....	....	....	....	1300	0
Wheat	0.03	0.42	14.	0.5	5.	440	0
Wheat bran	0.1	1.3	55.	1.2	11.3	460	0
Wheat mill run	0.1	1.1	25.	1.2	6.	460	0
Whey, dried	1.2	0.7	6.	9.	24.	900	0
Yeast, pure dried	1.3	1.2	1.	20.	60.	1500	0

[1] These values for vitamin A activity are averages; actual values may deviate greatly from these (see text, p. 6).
[2] Dotted lines indicate data not available.

be purchased on the basis of cost per pound of phosphorus.

Manganese

The chicken's manganese requirement is so high that even though some feedstuffs are fairly good sources of manganese (see Table 6), it is necessary to add manganese to the ration. Four to eight ounces of feeding grade manganese sulfate are usually added to each ton of mash. The amount to be added will depend upon the other ingredients of the mash, the purity of the manganese source, the age of birds, and the feeding method used. For example, four ounces manganese sulfate per ton are sufficient in an all-mash ration, but when a mash is to be supplemented with whole grains, eight ounces manganese sulfate per ton are required. Grains are usually poor sources of manganese.

Salt

Salt for poultry should be fine in texture, free-flowing, and evenly mixed into the mash. Iodized salt (containing at least 0.007 per cent iodine) should be used in starting and breeding rations, unless five per cent or more of fish meal is used. Oyster or clam shell fed to breeding hens will supply sufficient iodine to meet the requirement.

VITAMIN SOURCES

In addition to the vitamins supplied to poultry rations by the cereal grains, green feeds, and protein concentrates, supplementary sources of vitamin A, vitamin D_3, riboflavin, and the animal protein factor are often needed.

Fish oils of standardized vitamin A and vitamin D_3 potencies are commonly used as supplements in the ration. Oils should be fresh and of a potency guaranteed by chick assay for vitamin D. They should be stored only in a cool, dark place.

Dry vitamin A and D supplements containing guaranteed amounts of vitamins A and D_3 may be preferred to the fish oils because they are more easily mixed with the other feedstuffs. However, comparative price per vitamin unit should be the chief factor in determining which supplement is used.

Milk products: Dried skim milk, dried whey, dried buttermilk, and liquid milk products are valuable sources of protein and the B-complex vitamins. Milk products may be used to supply riboflavin, pantothenic acid, and choline to poultry rations (see Table 6). Milk products also supply a limited amount of the animal protein factor which is required for chick growth and hatchability.

Fermentation products resulting from microbial activity are often good riboflavin sources. Fermentation products are now being developed as sources of other vitamins also, particularly of the animal protein factor. Use of such products should be determined by analysis of each product, since the vitamin content of different products is likely to vary considerably.

Liver meal is a fairly rich source of riboflavin, pantothenic acid, choline, and the animal protein factor. **Liver and glandular meal** is usually less valuable as a vitamin source than liver meal.

Synthetic vitamins: Synthetically produced riboflavin, choline, vitamin D_3 and other less important vitamins are available for poultry feeding. These products may be used when their costs compare favorably with natural products. In making such a comparison the poultryman should remember that the natural sources of these vitamins usually provide other valuable nutrients too.

GREEN FEEDS

Green feeds are difficult to classify as energy or protein or vitamin sources, because they supply all of these nutrients. The most valuable contribution of either fresh or dried greens, however, is carotene (the plant equivalent of vitamin A).

Dried Greens

Dried greens such as alfalfa meal and dried, young grasses (oat, wheat, barley, and lawn grasses), can be used more conveniently than fresh products, but they are also more likely to vary in quality, particularly in carotene content. Machine dehydration should be carefully controlled in order to minimize heat damage to the proteins.

Fresh Greens

Both carotene and riboflavin are supplied by fresh greens such as alfalfa, clover, lawn clippings, green oats, green barley, green wheat, Sudan grass, kale, chard, green lettuce, young corn, or beet tops. In California, **alfalfa** can generally be depended upon during much of the year. **Ladino clover** is an excellent green crop that may out-yield alfalfa on some light soils; but it is shallow-rooted and demands frequent irrigation. **Sudan grass** may prove the best summer green-feed crop where water for irrigation is limited.

Actually, tests of the various types of fresh greens for vitamin A activity show that there are no great differences in value, and the poultryman can use whatever green feed he can grow or buy most economically. All green feeds should be cut when young and tender, because at this stage they are highest in nutritional value. With careful planning, many California poultrymen can provide a year-round daily supply of tender greens for their birds.

Fresh greens, however, are desirable but not absolutely necessary supplements to the poultry ration.

Growing pullets—particularly those over three months of age—may well be given all the greens they will eat. Laying hens should be limited to five pounds of fresh greens daily for each 100 birds, since more than this amount will make the egg yolks too dark for most commercial markets.

The practice of placing the birds on properly rotated green pastures is excellent for growing pullets but is not recommended for laying hens. Adult birds on pasture may destroy more green feed than they eat. Also, hens given unlimited amounts of green feeds will produce eggs of uneven yolk color.

Caution: Keep laying hens from eating cheeseweed (mallow). Consumption of this plant by hens has been shown at this Station to cause "pink white" deterioration in storage eggs. Cheeseweed often grows along roads and fence rows at the edges of fields. It may also be present in products such as dried alfalfa unless these are kept free from weeds. Other substances causing "pink white" include tree mallow, hollyhock, cottonseed meal, and kapok meal.

Silage

In dry-farming areas, or where irrigation water is not available, cereal grasses and other green crops which will grow during the rainy season may well be ensiled. The birds may not eat silage readily at first, but most flocks will soon learn to eat four to five pounds per day for each 100 hens. This is about the maximum amount that can be fed without adversely affecting egg yolk color.

Silos used on poultry ranches must have small diameters; otherwise the silage may spoil faster than it can be fed. The use of 50 to 60 pounds of molasses per ton of grasses will help preserve the product.

HARMFUL COMPONENTS OF FEEDSTUFFS

Harmful compounds are widely distributed in natural feedstuffs, and in the formulation of rations they must be considered separately from the recognized nutrients. Often these harmful substances are destroyed in processing or consumed in such small amounts that they cause no great harm. Besides, one feedstuff may

contain a substance capable of counteracting the harmful effects of another, so that the complete ration will have no injurious results.

Grains raised in certain areas of north central United States may contain poisonous amounts of **selenium.** The toxicity may be reduced by supplementing the ration with proteins, but in any event such grains can be safely fed only in limited amount.

Excessive amounts of **fluorine** may be present in rock phosphate; some of this must be removed (defluorinated) or the feeding level must be kept very low.

Alfalfa contains a factor which depresses growth in young chicks, and the level must therefore be kept below 5 per cent of the chick ration if most rapid growth is to be obtained. Growing pullets and laying hens can tolerate higher levels.

Raw soybean meal will not allow good growth of chicks because its methionine is unavailable. The difficulty may be overcome by the addition of the amino acid methionine, or by proper heat treatment of the meal, which will destroy the harmful factor or factors controlling the methionine.

Linseed oil meal contains a growth-inhibiting compound. The effect of this compound may be counteracted by increasing the level of pyridoxine in the ration; or the compound may be destroyed by processing the meal with water.

Charcoal should not be used in the ration because it may destroy or make unavailable some of the vitamins, especially vitamin A and riboflavin.

Chocolate meal has been found to be harmful to chickens, and should not be used.

SUGGESTED FEED FORMULAS AND FEEDING METHODS

As an aid to the compounding of high-quality, inexpensive feeds, we suggest below a number of sample formulas for birds of different ages and uses. We have considered some variations in relative costs and availability in developing these formulas, but it is entirely possible that under certain conditions other combinations of feedstuffs will prove better than these.

CHICK-STARTING MASHES

The chick-starting mashes listed in Table 7 are designed for use with chicks which are to be reared primarily for egg production. These mashes conform to the allowances presented in Table 3. A mixture of two or more ground grains (corn, wheat, barley or sorghums) should be used, but the proportions may be varied as current prices warrant. These mashes will contain approximately 20 per cent crude protein and should not be diluted with other feeds until the chicks are six weeks old, when whole grains may be fed in small amounts (up to one-fifth the weight of the mash). The amount of grain fed may be gradually increased, until the birds are receiving equal amounts of mash and grain at 12 weeks. When whole grains are fed, the birds should be given hard, insoluble grit to aid the gizzard in its grinding function.

BROILER-FRYER MASHES

The formulas for broiler-fryer mashes given in Table 8 have been found to promote the rapid growth necessary for meat birds. These formulas contain low levels of fibrous cereal materials (barley and mill feeds) and alfalfa meal (which contains growth inhibitors as well as a high level of fiber), hence are different from the formulas suggested for replacement birds. These mashes are calculated to conform to the allowances presented in Table 3.

TABLE 7—Formulas for representative chick-starting mashes.

Ingredients	No. 1	No. 2	No. 3	No. 4	No. 5
	lbs. per ton	lbs. per ton	lbs. per ton	lbs. per ton	lbs. per ton
Fish meal, 65% crude protein	200	150	100	60	40
Soybean oil meal	150	250	350	500	500
Alfalfa meal[1]	100	100	100	100	100
Dried skim milk	0	0	50	0	0
Dried whey	0	50	50	0	100
Salt	10	10	10	15[2]	15[2]
Wheat bran or mill run	320	240	160	160	160
Ground grains	1178	1153	1128	1103	1023
Manganese sulfate, 85% pure	¼	¼	¼	¼	¼
Ground limestone or shell	40	45	40	40	40
Bone meal, special steamed (or equivalent phosphorus source)	0	0	10	20	20
Vitamin D_3 source (400 units per gram, or 181,000 units per lb.)[3]	2	2	2	2	2
Riboflavin[4]	0.8 gram	0.4 gram	0.2 gram	1.0 gram	...

[1] Should contain carotene equivalent to at least 67,000 International Units of vitamin A per pound.
[2] Iodized salt, containing 0.007 per cent iodine, is advised when high levels of soybean oil meal or limited amounts of fish meal are used.
[3] Other potency products may be used to supply the same amount of vitamin D_3. For example, only 0.4 pound is required if the product contains 2000 A.O.A.C. units per gram, or 908,000 A.O.A.C. units per lb.
[4] Any riboflavin supplement may be used if it supplies the specified amount of riboflavin per ton (1 gram = 1000 milligrams [mg.]). Amounts of riboflavin or other supplements, which are added in very small amounts, should be premixed with ground grains or soybean oil meal before mixing.

TABLE 8—Suggested formulas for broiler-fryer mashes.

Ingredients	No. 6	No. 7	No. 8
	lbs. per ton	lbs. per ton	lbs. per ton
Fish meal, 65% crude protein	100	0	190
Meat scraps, 55% crude protein	75	240	0
Soybean oil meal	300	200	250
Sesame seed oil meal	0	200	0
Alfalfa meal	50[1]	80[1]	80
Wheat bran or mill run	200	0	0
Corn, yellow, ground	500	800	900
Milo, ground	0	240	0
Barley, ground	300	0	100
Wheat, ground	400	200	310
Bone meal, special steamed (or equivalent phosphorus source)	0	0	15
Limestone or shell flour	40	20	40
Salt	10	20[2]	10
Manganese sulfate, 85% pure	½	½	½
Fermentation product containing at least 100 milligrams riboflavin per pound	20	0	0
Riboflavin	0	1 gram	2 grams
Vitamin A source (3000 International Units per gram, or 1,362,000 Int. Units per pound)	2	0	2
Vitamin D_3 source (400 A.O.A.C. units per gram, or 181,000 A.O.A.C. units per pound)[3]	2	2	2

[1] Should contain carotene equivalent to at least 67,000 I.U. of vitamin A per pound.
[2] Iodized salt, containing 0.007 per cent iodine, is advised when high levels of soybean oil meal or limited amounts of fish meal are used.
[3] Products of other potencies can be used (see footnote 3, table 7).

TABLE 9—Suggested formulas for laying mashes.

Ingredients	No. 9	No. 10	No. 11	No. 12	No. 13
	lbs. per ton	lbs. per ton	lbs. per ton	lbs. per ton	lbs. per ton
Fish meal, 65% crude protein	200	100	80	40	0
Meat scraps, 55% crude protein	0	0	0	50	100
Soybean oil meal	250	400	450	400	450
Dried whey	0	0	0	50	50
Alfalfa meal[1]	120	100	100	100	100
Bone meal, special steamed (or equivalent)	20	40	45	35	30
Ground limestone or shell	50	40	40	40	30
Salt	20	20	20[2]	20[2]	20[2]
Wheat bran or mill run	300	160	160	200	200
Ground grains	1040	1124	1089	1050	1005
Manganese sulfate, 85% pure	½	½	½	½	½
Vitamin A source (3000 Int. Units per gram)	4[3]	6	6	6	6
Vitamin D_3 source (400 A.O.A.C. units per gram)	10[3]	10	10	10	10

[1] Should contain carotene equivalent to at least 67,000 I.U. of vitamin A per pound.
[2] Iodized salt, containing 0.007 per cent iodine, is advised when high levels of soybean oil meal or limited amounts of fish meal are used.
[3] May be supplied by products with different potencies (for example, 2.4 pounds 5000 I.U. vitamin A product plus 2 pounds 2000 vitamin D product or 10 pounds 1200 A, 400 D product).

TABLE 10—Suggested mash formulas for breeding hens.

Ingredients	No. 14	No. 15	No. 16
	lbs. per ton	lbs. per ton	lbs. per ton
Fish meal, 65% crude protein	200	100	50
Meat scraps, 55% crude protein	0	0	50
Soybean oil meal	250	400	400
Dried whey	0	50	100
Alfalfa meal[1]	120	120	120
Bone meal, special steamed (or equivalent)	20	40	30
Ground limestone or shell	50	40	40
Salt	20	20[2]	20[2]
Wheat bran or mill run	300	160	200
Ground grains	1026	1056	976
Manganese sulfate, 85% pure	½	½	½
Vitamin A source (3000 Int. Units per gram)	4[3]	4	4
Vitamin D_3 source (400 A.O.A.C. units per gram)	10[3]	10	10
Riboflavin[4]	1.6 grams	1.4 grams	1.0 gram

[1] Should contain at least 67,000 I.U. of vitamin A activity per pound.
[2] Iodized salt, containing 0.007 per cent iodine, is advised when high levels of soybean oil meal or limited amounts of fish meal are used.
[3] May be supplied by products with different potencies (for example, 2.4 pounds 5000 I.U. vitamin A product plus 2 pounds 2000 vitamin D product or 10 pounds 1200 A, 400 D product).
[4] Any riboflavin supplement may be used which supplies the specified amount of riboflavin per ton.

When grain is appreciably cheaper than mash, it may be profitable to dilute the broiler mash with whole grains after the sixth week. If this is done, hard, insoluble grit should also be made available to the birds. Not more than one-fourth of the ration should be made up of whole grains.

LAYING MASHES

Representative formulas for laying mashes, which appear in Table 9, contain about 20 per cent crude protein and also conform to other standards of Table 3. These mashes are designed to be fed with supplemental grains in the ratio of half mash to half grain, during periods of high production. Crushed limestone or shell, and hard, insoluble grit should be fed free choice. If an all-mash ration is desired, the amounts of ground grains may be increased by 1500 pounds for a 3500-pound mix. By omitting the ground grains from these formulas, the poultryman has a concentrate which may be used satisfactorily with grains raised by himself or bought locally.

BREEDING MASHES

Breeding mashes differ from laying mashes only in that they contain higher levels of riboflavin, the animal protein factor, and other water-soluble vitamins. Grains, calcium sources, and grit should be fed in the same manner as with laying mashes (above).

Representative formulas are given in Table 10.

ALL-PURPOSE MASHES

The preceding formulas are for specific purposes, but the differences between them are small. It is obvious that it is not absolutely necessary to use different formulas for each stage of growth and development. In fact it may be unprofitable for a farmer who mixes his own feed to make several formulas. A larger mixer, however, may effect some savings in cost by making several mashes.

TABLE 11—All-purpose mash formulas.

Ingredients	Starting and growing	Laying and breeding
	lbs. per ton	lbs. per ton
Corn, yellow, ground	600	200
Wheat, ground	270	200
Barley, ground	200	600
Alfalfa meal, dehydrated	80	150
Wheat bran or mill run	300	300
Soybean oil meal, 44% protein	200	200
Fish meal, at least 65% protein	150	150
Dried whey	50	50
Dried skim milk	50	50
Liver meal	40	40
Limestone or shell, ground	30	30
Bone meal, special steamed	24	24
Salt	10	10
Manganese sulfate, 85% pure	½	½
Feeding oil (400D-3000A)	5	5
Riboflavin	2 grams	2 grams
	2,009½ lbs.	2,009½ lbs.

A basic mash formula has for some years been fed successfully throughout the bird's whole life at this Station. The only time the formula is changed is when the pullets are about five months old. At this time the level of corn is reduced from 600 to 200 pounds per ton, and the barley is increased by an equal amount; also, the level of alfalfa meal is increased to 150 pounds and the wheat reduced to 200 pounds. A mixture of approximately equal parts of whole corn, wheat, and barley is fed from the sixth week onward. The amount of grain fed is gradually increased until the birds are receiving equal amounts of mash and grain at 12 weeks. The grain is fed twice daily in the litter. Since this mash is also used for breeding hens, its vitamin levels are quite high.

The formulas for this all-purpose mash are given in Table 11.

Note: This formula was designed to supply excesses of both water- and fat-soluble vitamins, because at the time of its development we did not know the bird's exact requirements for these nutrients. Now that these requirements are more exactly known, the amounts of vitamins in the mash can safely be lowered. The basic formula as given above has been changed very little at this Station, however, because most of the birds raised on the mash are used for breeding experiments. In breeding experiments it is necessary to maintain as constant an environmental condition as possible from one year to the next.

For a further discussion of feeding methods, see the mimeographed publication "What Is the Best Way to Feed Chickens?" obtainable from the Division of Poultry Husbandry, University of California, Berkeley 4.

141

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